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AASERT FINAL REPORT - High Speed Heterostructure Transistors

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The growth and characterization of the III-V nitrides has been the focus of intense effort. A major problem plaguing nitride growth has been the absence of a good substrate to grow on. Currently sapphire and 6H-SiC are the substrates of choice for nitride growth with approximately equal results, although growth on sapphire yields slightly better results. We have addressed this problem in a fundamental and innovative way and given fresh insight into the considerations that must guide subsequent substrate development.

Practically all epitaxial layers of GaN and AlN grown by MBE and CVD contain a dense network of threading defects; these defects originate at the substrate/film interface and often penetrate through the whole film. Lattice mismatch (quite large for 6H-SiC and sapphire) is often cited as a cause of these defects. However high-resolution TEM has shown that lattice mismatch in wurtzite nitride films can be completely relieved by the formation of a network of edge dislocations at the substrate/film interface and can be confined to the vicinity of the interface. A second type of defect, the double positioning boundary (DPB), is commonly cited as the source of the threading defects. Recent TEM experiments showed that vertical defects do not form on atomically flat substrate regions, forming instead at substrate steps. We showed that DPBs do not describe the defects observed in wurtzite GaN. We found the defects to be boundaries between differently stacked domains created at substrate steps. We proposed the defects be called stacking mismatch boundaries (SMB).

Theoretical considerations showed that SMBs are inevitable on SiC and sapphire substrates because they invariably contain numerous substrate steps. Every substrate step leads with high probability to an SMB threading defect. The fundamental origin of this stacking mismatch was found to be the difference in stacking order between the substrate and expitaxial film. SMBs can be avoided if the substrate and epitaxial film have the same stacking order. Wurtzite GaN is hexagonal (2H). We recommend that substrate development efforts focus on other hexagonal (2H) materials such as ZnO and bulk GaN in order to avoid SMBs.

This period marked the success of a long effort to characterize the nitride heterojunction band lineups by x-ray photoemission spectroscopy. We report a table of valence-band discontinuities for the various nitride heterojunctions:

Bottom \ Top	InN	GaN	AlN
InN		0.59 ± 0.24 eV	1.32 ± 0.14 eV
GaN	0.93 ± 0.25 eV		0.57 ± 0.22 eV
AlN	1.71 ± 0.20 eV	0.60 ± 0.24 eV	